

What is claimed is:

1. A power conversion circuit having a power transformer, four semiconductor switching elements connected as a bridge across an input to the power conversion circuit and connected to a primary winding of the power transformer to reverse current through the
5 primary winding, a split secondary winding on the power transformer, a first unidirectional current conducting device connected from one end of the split secondary winding to an inductor, a second unidirectional current conducting device connected from a second end of the split secondary winding to the inductor, the inductor and a connection to an
10 interconnection between two halves of the split secondary winding being connected to an output of the power conversion circuit, an injection voltage source connected to the primary winding of the power transformer for applying an injection voltage to the primary winding in addition to an input voltage to the primary winding via the semiconductor switching elements connected as a bridge.

2. The power conversion circuit according to claim 1, wherein the injection
15 voltage source is a winding on an injection voltage transformer, said winding being connected in series with said primary winding of the power transformer.

3. The power conversion circuit according to claim 2, wherein the injection voltage transformer has a further winding connected to a capacitor.

4. The power conversion circuit according to claim 1, wherein the unidirectional
20 current conducting devices are semiconductor switching devices.

5. A power conversion circuit having a power transformer with at least one primary winding and at least one secondary winding, a primary circuit connected with the primary winding and adapted to deliver a main primary current alternating in direction through the primary winding, a secondary circuit connected to the secondary winding and
25 adapted to receive a main secondary current from the secondary winding and to deliver electrical power to a load, at least one semiconductor unidirectional current conducting device in at least one of the primary and secondary circuits and adapted alternately to conduct a main current passing through an associated one of the windings of the power transformer; the improvement comprising:

an injection voltage source connected to apply a supplemental reverse bias voltage to the semiconductor unidirectional current conducting device sufficient to terminate forward conduction in the device and to deplete carriers in the device at times prior to each reverse biasing of the device by an alternating of the main primary current causing a reversal of voltage across the associated power transformer winding.

6. The power conversion circuit according to claim 5, wherein the at least one semiconductor unidirectional current conducting device comprises two such devices each connected in series with an associated secondary winding.

7. The power conversion circuit according to claim 5, wherein the injection voltage source is coupled to the at least one primary winding to develop across the at least one secondary winding a voltage producing across the semiconductor unidirectional current conducting device the supplemental reverse bias voltage.

8. The power conversion circuit according to claim 6, wherein the injection voltage source is connected in current conducting relation with the at least one power transformer primary winding to develop across each secondary winding of the power transformer associated with a semiconductor unidirectional current conducting device the supplemental reverse biasing voltage biasing each of the semiconductor unidirectional current conducting devices.

9. The power conversion circuit according to claim 7, wherein the injection voltage source is an auxiliary transformer having a first winding connected in series with the at least one primary winding of the power transformer and having a second winding connected to a capacitor, whereby current developed in the first winding of the auxiliary transformer is supplied through the at least one primary winding of the power transformer timed to generate a voltage in the secondary winding of the power transformer producing the supplemental reverse bias voltage.

10. The power conversion circuit of claim 5, wherein the at least one semiconductor unidirectional current conducting device comprises at least one rectifying diode connected in series with the at least one secondary winding between the at least one secondary winding and a load connection.

11. The power conversion circuit according to claim 10, wherein the at least one rectifying diode comprises a pair of rectifying diodes, each connected in series with at least one power transformer secondary winding.

5 12. The power conversion circuit according to claim 5, wherein the at least one semiconductor unidirectional current conducting device comprises at least one rectifying electrically controlled semiconductor switching device connected in series with the at least one secondary winding between the at least one secondary winding and a load connection.

10 13. The power conversion circuit according to claim 12, wherein the at least one electrically controlled semiconductor switching device comprises a pair of rectifying electrically controlled semiconductor switching devices, each connected in series with at least one power transformer secondary winding.

14. The power conversion circuit according to claim 12, wherein the at least one electrically controlled semiconductor switching device is a synchronous rectifier.

15 15. The power conversion circuit according to claim 13, wherein the pair of electrically controlled semiconductor switching devices is a pair of synchronous rectifiers, each connected in series with at least one power transformer secondary winding.

20 16. The power conversion circuit according to claim 6, wherein the power transformer has a pair of secondary windings each connected in series with one of the semiconductor unidirectional current conducting devices, the primary circuit comprises a circuit for delivering an alternating current through the at least one primary winding to produce alternating voltages across the secondary windings alternately biasing the semiconductor unidirectional current conducting devices into and out of conduction, the injection voltage source being a source of alternating voltage connected with the at least one primary winding of the power transformer to produce alternately in the pair of secondary
25 windings a first supplemental reverse bias voltage reverse biasing a first of the pair of semiconductor unidirectional current conducting devices and a second supplemental reverse bias voltage reverse biasing a second of the pair of semiconductor unidirectional current conducting devices.

17. The power conversion circuit according to claim 16, wherein the at least one primary winding and the secondary windings of the power transformer are wound such that when the injection voltage produces the first supplemental reverse bias voltage reverse biasing the first of the pair of semiconductor unidirectional current conducting devices, the injection voltage also produces a first supplemental forward bias voltage forward biasing the second of the devices, and when the injection voltage produces the second supplemental reverse bias voltage reverse biasing the second of the semiconductor unidirectional current conducting devices, the injection voltage also produces a second supplemental forward bias voltage forward biasing the first of the devices.

18. The power conversion circuit according to claim 16, wherein the circuit for delivering an alternating current through the at least one primary winding comprises a plurality of electrically controlled unidirectional semiconductor switches connected in a bridge configuration between a DC input connection and the at least one primary winding of the power transformer.

19. The power conversion circuit according to claim 18, wherein the at least one primary winding of the power transformer and the injection voltage source are connected in series and connected to a junction of a pair of the electrically controlled unidirectional semiconductor switches to deliver a current to the junction of the switches, whereby substantially zero voltage switching of the switches is assured.

20. The power conversion circuit according to claim 16, wherein the circuit for delivering an alternating current through the at least one primary winding comprises a full bridge circuit coupled to the at least one primary winding and adapted to be connected across a DC source.

21. The power conversion circuit according to claim 20, wherein the full bridge switching circuit comprises four electrically controlled unidirectional semiconductor switches.

22. The power conversion circuit according to claim 21, wherein the four electrically controlled unidirectional semiconductor switches are electrically controlled to provide current in a first direction through the at least one primary winding, a short across the at least one primary winding and the injection voltage source, current in a reverse direction
5 through the at least one primary winding, and then again a short across the primary winding and the injection voltage source, whereby the first and second secondary windings produce voltages of opposite polarities with intervening periods of a substantially lower voltage induced therein by the injection voltage.

23. The power conversion circuit according to claim 22, wherein the at least one
10 primary winding of the power transformer is connected at one end to a junction of a pair of the electrically controlled switches, and in series with the injection voltage source, the injection voltage source being connected to a junction of a further pair of the electronically controlled switches, the at least one primary winding and injection voltage source delivering current substantially triangular in its plot of current versus time to the junctions of the pairs of
15 electrically controlled switches to assure substantially zero voltage switching thereby.

24. The power conversion circuit according to claim 23, the injection voltage source producing substantially an AC square wave voltage.

25. The power conversion circuit according to claim 24, wherein the injection voltage source comprises an auxiliary transformer having a primary connected in series with
20 the at least one primary of the power transformer and having a secondary connected to a capacitor connected to ground.

26. A power conversion circuit having a power transformer with a primary winding and at least one secondary winding, an input circuit connected to the primary winding, an output circuit connected with the at least one secondary winding and having a
25 semiconductor rectifying means coupled in current conducting relation with the at least one secondary winding, an inductor coupled in current conducting relation between the semiconductor rectifying means and an output load connection; the improvement comprising:
means for applying a first, relatively low reverse bias voltage to the semiconductor rectifying means to halt forward conduction and deplete carriers in the
30 semiconductor rectifying means prior to each application to the semiconductor rectifying means of a reverse bias larger than the first, relatively low reverse bias voltage.

27. The power conversion circuit according to claim 26, wherein the means for applying a reverse bias voltage comprises means for injecting a supplemental voltage on the primary winding of the power transformer in addition to a main excitation voltage applied by the input circuit to the primary winding.

5 28. The power conversion circuit according to claim 27, wherein the means for injecting a supplemental voltage comprises an auxiliary transformer connected with the primary winding of the power transformer to apply a supplemental voltage that is an alternating voltage producing in the at least one secondary winding of the power transformer the first, relatively low reverse bias voltage.

10 29. The power conversion circuit according to claim 28, wherein the semiconductor rectifying means comprises first and second semiconductor rectifying devices connected with first and second secondary windings of the power transformer, the auxiliary transformer applies an alternating voltage of first and second primary voltage levels to produce in the first and secondary windings first and second secondary voltage levels reverse
15 biasing the first and second rectifying devices, respectively.

30. The power conversion circuit according to claim 26, wherein the semiconductor rectifying means comprises a pair of semiconductor unidirectional current conducting devices, and the means for applying a reverse bias voltage alternately reverse biasing the semiconductor unidirectional current conducting devices and driving carriers from
20 that device into the other, conducting unidirectional current conducting device.

31. The power conversion circuit according to claim 30, wherein the means for applying a first, relatively low reverse bias voltage comprises means for applying an alternating voltage to the primary winding of the power transformer, wherein the input circuit comprises a plurality of semiconductor switching means, connected with the power
25 transformer primary winding and the means for applying an alternating voltage, the means for applying an alternating voltage being connected into the primary circuit to inject alternating current into the semiconductor switching means to assure substantially zero voltage switching thereof.

32. In a method of power conversion including switching a DC voltage to supply a power transformer primary, and rectifying with at least a first semiconductor rectifier a transformer output from a secondary of the power transformer; the improvement comprising applying to the semiconductor rectifier a relatively low reverse bias voltage to deplete at least one semiconductor junction of the semiconductor rectifier of carriers in advance of each application to the semiconductor rectifier of a relatively high reverse biasing power transformer secondary voltage excursion.

33. The method according to claim 32, wherein rectifying with a semiconductor rectifier a power transformer output comprises rectifying the power transformer output with at least a second semiconductor rectifier; the improvement further comprising applying to the second semiconductor rectifier a relatively low reverse bias voltage to deplete at least one semiconductor junction of the second semiconductor rectifier of carriers in advance of each application of a relatively high reverse biasing power transformer secondary voltage excursion.

34. The method according to claim 32, wherein applying to the semiconductor rectifier a reverse bias comprises applying an alternating injection voltage waveform to the primary of the power transformer to produce in a secondary of the power transformer the reverse bias voltage applied to the semiconductor rectifier.

35. The method according to claim 33, wherein applying to the first and second semiconductor rectifiers a reverse bias comprises applying an alternating injection voltage waveform to the primary of the power transformer to produce in a secondary of the power transformer the reverse bias voltages applied to the first and second semiconductor rectifiers.

36. The method according to claim 34, wherein applying an injection voltage comprises providing an auxiliary transformer having a first winding connected to the primary of the power transformer and having a second winding connected through a capacitor to ground.

37. The method according to claim 33, further comprising applying to each semiconductor rectifier the reverse bias when the remaining semiconductor rectifier is conducting.

38. The method according to claim 37, wherein applying to each semiconductor rectifier the reverse bias comprises driving carriers out of the reverse biased rectifier and into the conducting rectifier.

5 39. The method according to claim 37, wherein applying the reverse bias further comprises applying the reverse bias to each semiconductor rectifier before application of a higher voltage reverse biasing voltage thereto generated by the switched DC voltage supplied to the power transformer primary.

10 40. The method according to claim 32, further comprising supplying an alternating current to a semiconductor switching circuit that switches the DC voltage to supply the power transformer primary to assure zero voltage switching thereof.

15 41. The method according to claim 34, further comprising providing a full bridge semiconductor switching circuit as an input across the power transformer primary and a source of the reverse bias voltage, activating the switching circuit to apply as the input a first voltage of a first polarity and a second voltage of an opposite polarity and between each first and opposite polarity voltage, substantially no voltage.